Chapter 12

RUNOFF REDUCTION METHODOLOGY

Table of Contents

FIGURES

TABLES

12.0 Introduction

Virginia's proposed Stormwater Management Program Permit Regulations (4 VAC 50-60 et al) include water quality and quantity requirements based, in part, on the Virginia Runoff Reduction Method. The Runoff Reduction Method (RRM) was developed for DCR by the Center for Watershed Protection in order to promote better stormwater design and as a tool for compliance with Virginia's proposed regulations. There several shortcomings to existing stormwater design practices that the method seeks to overcome.

This method is supported by recent stormwater research findings concerning the runoff reduction and pollutant removal capabilities of various stormwater best management practices (BMPs). More information and documentation concerning the development of the Virginia Runoff Reduction Method can be found in a Technical Memorandum prepared by the Center for Watershed Protection and the Chesapeake Stormwater Network. The memorandum can be downloaded at: www.cwp.org > Resources > Controlling Runoff & Discharges > Stormwater Management.

The method is accompanied by a site planning and compliance spreadsheet. The spreadsheet is designed to help users plan combinations of stormwater BMPs for a particular site in order to meet the standards in the proposed regulations. There is one spreadsheet for new development and a separate one for redevelopment (prior developed lands).

As a general overview, the following characteristics apply to the Virginia Runoff Reduction Method and associated spreadsheets:

- **Total Phosphorus (TP)** is used as the target pollutant for compliance with proposed water quality criteria (4 VAC50-60-63 through 65). Total Nitrogen (TN) is also calculated and BMP designs address TN removal, as well as the removal of other stormwater pollutants.
- Compliance is based on the overall site; however, stormwater BMP planning can be done on a drainage area basis. The spreadsheet has tabs for multiple drainage areas.
- Each site also has a **Treatment Volume (T_v)**. The method uses post-development land covers (forest and open space, managed turf, impervious cover) to compute the T_v.
- Stormwater BMPs are assigned **Runoff Reduction (RR)** and **Pollutant Removal (PR)** rates. These rates vary based on the "level of design" used. Level 1 designs represent good, current design standards with regard to sizing and BMP features. Level 2 BMPs have design enhancements to boost runoff reduction and pollutant removal performance. Each Level 1 and 2 design has associated design standards and specifications that should be followed to achieve the assigned RR and PR rates.
- There is a tab in the spreadsheet for **Channel and Flood Protection.** This tab is designed to assist users with compliance with the water quantity part of the proposed regulations (4 VAC50-60-66). The spreadsheet assists users with computing runoff volumes and Curve Numbers (CN). The user must then use available hydrologic and hydraulic models and programs to calculate peak discharges for various design storms and verify compliance with the various conditions of the Water Quantity section. If Runoff Reduction practices are used for Water Quality compliance, then these are given credit for Channel Protection and Flood Control, chiefly by allowing the user to compute an Adjusted CN. The designer, with

concurrence from the local program authority, may also take other hydrologic "credits" for RR practices, such as increasing the time of concentration (Tc).

- In the spreadsheet, blue boxes require user input; gray boxes are calculation cells, and yellow boxes are constant values. The user should only add values to the blue boxes.

The RR Method relies on a three-step compliance procedure, as described below.

Step 1: Apply Site Design Practices to Minimize Impervious Cover, Grading and Loss of Forest Cover

This step focuses on implementing Environmental Site Design (ESD) practices during the early phases of site layout. The goal is to minimize impervious cover and mass grading, and maximize retention of forest cover, natural areas and undisturbed soils (especially those most conducive to landscape-scale infiltration). The RR Method uses a spreadsheet to compute runoff coefficients for forest, disturbed soils, and impervious cover and to calculate a site-specific target treatment volume and phosphorus load reduction target.

Step 2: Apply Runoff Reduction (RR) Practices

In this step, the designer experiments with combinations of nine Runoff Reduction practices on the site. In each case, the designer estimates the area to be treated by each Runoff Reduction practice to incrementally reduce the required treatment volume for the site. The designer is encouraged to use Runoff Reduction practices in series within individual drainage areas (such as rooftop disconnection to a grass swale to a bioretention area) in order to achieve a higher level of runoff reduction.

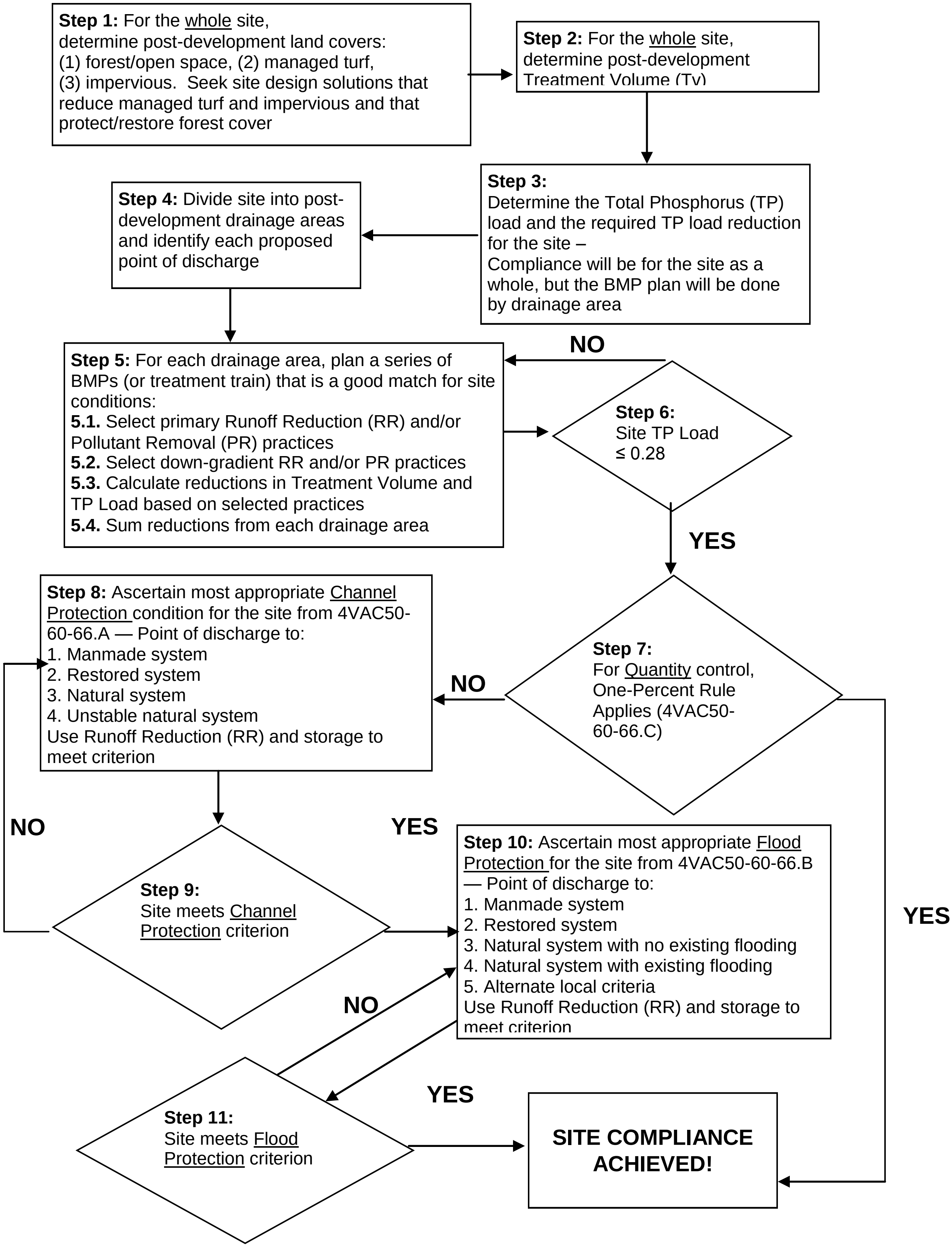
Step 3: Compute Pollutant Removal (PR) By Selected BMPs

In this step, the designer uses the spreadsheet to see whether the phosphorus load reduction has been achieved by the application of Runoff Reduction practices. If the target phosphorus load limit is not reached, the designer can select additional, conventional BMPs – such as filtering practices, wet ponds, and stormwater wetlands – to meet the remaining load requirement. In reality, the process is iterative for most sites. When compliance cannot be achieved on the first try, designers can return to prior steps to explore alternative combinations of Environmental Site Design, Runoff Reduction practices, and Pollutant Removal practices to achieve compliance.

A possible Step 4 would involve paying an offset fee (or fee-in-lieu payment) or providing off-site mitigation to compensate for any load that cannot feasibly be met on particular sites. The local government or program authority would need to have a watershed or regional planning structure for stormwater management in order to make this option available for sites within the jurisdiction. The fee would be based on the phosphorus "deficit" – that is, the difference between the target reduction and the actual site reduction after the designer makes his or her best effort to apply Runoff Reduction and Pollutant Removal practices. A related, but simpler option would be to allow a developer to conduct an off-site mitigation project in lieu of full on-site compliance.

A flow chart of the Runoff Reduction Compliance Methodology is on the following page.

Figure 12.1. Runoff Reduction Method Flow Chart



12.1 STEP-BY-STEP INSTRUCTIONS FOR USING RRM THE SITE PLANNING AND COMPLIANCE SPREADSHEET

The numbering in these instructions generally follows the process outlined in Document A (flowchart). Tab references refer to the appropriate tab in the spreadsheet. Line references refer to the appropriate line in the spreadsheet.

12.1.1 TAB 1: Site Data

1.A Use environmental site design (ESD) techniques to reduce impervious cover and maximize forest and open space cover. This will affect the post-development treatment volume and pollutant load.

1.B The Target Total Phosphorous Load is 0.41 pounds per acre per year (indicated on **line 18**).

1.C For the site, indicate post-development impervious, managed turf, and forest/open space land cover in **lines 23-25**. Guidance for various land covers is provided in **Table 12.1** (on the next page).

2. From the land cover input, a weighted site runoff coefficient (R_v) will be calculated (**line 47**), as will the required Post Development Treatment Volume (**lines 49-50**).

3. A Post Development TP Load, and the required TP load reduction will be calculated based upon the Post Development Treatment Volume (**lines 51-52**). A Total Nitrogen (TN) reduction will also be calculated in **line 51** for information purposes. Compliance is based on TP.

12.1.2 TAB 2: Drainage Area A (D.A. A)

4. If the site has multiple discharge points, or complex treatment sequences, it may be beneficial to divide the site into more than one drainage area. Indicate the post-development impervious, managed turf, and forest/open space land cover for Drainage Area A in **lines 11-13**.

5.1.A. Apply Runoff Reduction (RR) Practices to the drainage area to reduce post-development treatment volume and load by indicating in **column G** the number of acres to be treated by a given RR practice. Note that some RR practices are divided into turf area and impervious area to be treated. The site designer should select the most strategic locations on the site to place RR practices (e.g., drainage areas with the most developed land). This will likely be an iterative process. The available RR Practices include:

- Green roof
- Impervious surface disconnection
- Permeable pavement
- Grass channel
- Dry swale
- Bioretention
- Infiltration
- Extended detention pond
- Sheetflow to conservation area or filter strip

Table 12.1. Land Cover Guidance for Virginia Runoff Reduction Spreadsheet

IMPERVIOUS COVER
• Roadways, driveways, rooftops, parking lots, sidewalks, and other areas of impervious cover. This category also includes the surface area of stormwater BMPs that: (1) are wet ponds, OR (2) replace an otherwise impervious surface (e.g., green roof, pervious parking).[1]
MANAGED TURF
Land disturbed and/or graded for eventual use as managed turf: • Portions of residential yards that are graded or disturbed, including yard areas, septic fields, residential utility connections • Roadway rights-of-way that will be mowed and maintained as turf Turf areas intended to be mowed and maintained as turf within residential, commercial, industrial, and institutional settings
FOREST & OPEN SPACE
Land that will remain undisturbed OR that will be restored to a hydrologically functional state: • Portions of residential yards that will NOT be disturbed during construction • Portions of roadway rights-of-way that, following construction, will be used as filter strips, grass channels, or stormwater treatment areas; MUST include soil restoration or placement of engineered soil mix as per the design specifications • Community open space areas that will not be mowed routinely, but left in a natural vegetated state (can include areas that will be bush hogged no more than four times per year) • Utility rights-of-way that will be left in a natural vegetated state (can include areas that will be bush hogged no more than four times per year) • Surface area of stormwater BMPs that are NOT wet ponds, have some type of vegetative cover, and that do not replace an otherwise impervious surface. BMPs in this category include bioretention, dry swale, grass channel, ED pond that is not mowed routinely. stormwater wetland, soil amended areas that are vegetated, and infiltration practices that have a vegetated cover. • Other areas of existing forest and/or open space that will be protected during construction and that will remain undisturbed. These include wetlands. <u>Operational & Management Conditions for Land Cover in Forest & Open Space Category:</u> • Undisturbed portions of yards, community open space, and other areas that will be considered as forest/open space must be shown outside the LOD on approved E&S plans AND demarcated in the field (e.g., fencing) prior to commencement of construction. • Portions of roadway rights-of-way that will count as forest/open space are assumed to be disturbed during construction, and must follow the most recent design specifications for soil restoration and, if applicable, site reforestation, as well as other relevant specifications if the area will be used as a filter strip, grass channel, bioretention, or other BMP • All areas that will be considered forest/open space for stormwater purposes must have documentation that prescribes that the area will remain in a natural, vegetated state. Appropriate documentation includes: subdivision covenants and restrictions, deeded operation and maintenance agreements and plans, parcel of common ownership with maintenance plan, third-party protective easement, within public right-of-way or easement with maintenance plan, or other documentation approved by the local program authority • While the goal is to have forest/open space areas remain undisturbed, some activities may be prescribed in the appropriate documentation, as approved by the local program authority: forest management, control of invasive species, replanting and revegetation, passive recreation (e.g., trails), limited bush hogging to maintain desired vegetative community, etc.
[1] Certain stormwater BMPs are considered impervious with regard to the land cover computations. These BMPs are still assigned Runoff Reduction and/or Pollutant Removal rates within the spreadsheet, so their “values” for stormwater management are still accounted for. The reason they are considered impervious is that they either do not reduce runoff volumes (e.g., wet ponds) OR their Runoff Reduction rates are based on comparison to a more conventional land cover type (e.g., green roofs, pervious parking).

5.1.B. Based upon the runoff reduction capability of the selected BMP, the spreadsheet will calculate the Runoff Reduction Volume in **column I** and the Remaining Runoff Volume in **column J.**

5.1.C. These practices also have a pollutant removal efficiency (**column K**), which will be applied to the remaining runoff volume (after runoff reduction has been applied). The spreadsheet will calculate the pollutant removal in **column N**.

5.2.A. If a secondary RR practice or a pollutant removal practice will be used in sequence downstream of the primary RR practice (for example, 2 acres of impervious rooftop are to be treated first with a green roof, and then, after discharge from the roof, the water will be conveyed via a dry swale), select the downstream RR practice from the pull-down menu in **column P** (click on the blue box in column P to see the pull-down menu). The spreadsheet will calculate the Remaining Runoff Volume and then direct it to the selected downstream RR practice via **column H**, and the remaining phosphorus load to **column L.** Sequences of three or more practices can be accommodated.

5.2.B. Select all the RR practices that will be used for the drainage area. Note that it is possible for a RR practice to be a downstream practice for one area, and a primary practice for another (Using the example above, a dry swale can receive discharge from a green roof and can also receive runoff directly from an impervious parking area.). It is also possible for more than one primary practice to be directed to the same downstream practice. However, the spreadsheet will not allow runoff from one primary practice to be diverted into two different downstream practices. If a site design calls for this, the site will need to be divided into separate drainage areas, or the design worksheet may be used instead of the spreadsheet.

5.3.A. From the selected RR practices, the total runoff reduction will be calculated on **line 80**, along with the TP load reduction achieved on **line 81.**

5.3.B. The phosphorous load calculations on **lines 80 and 81** account for both the runoff reduction and pollutant removal achieved by runoff reduction practices. Additional practices, including wet swales, filters, ponds, wetlands and manufactured devices remove phosphorous from runoff via settling, filtering, biological uptake and other processes, but do not achieve runoff reductions. These practices should be viewed as supplemental to runoff reduction measures. **Lines 86-118** account for pollutant removal from practices that do not provide runoff reduction. Indicate acres of turf or impervious cover that drain to these practices *without* first being treated by another practice in **Column D.** The remaining phosphorus load and (unchanged) runoff volume can then be directed to a downstream practice chosen in **Column K.** Runoff volume and phosphorus load from upstream practices are included **Columns F and G**, respectively, for these practices.

5.3.C. The TP load reduction for the practices on **lines 86-118** are calculated in **Column I** and summed on **cell I-120**. This load is added to the phosphorus removal achieved by upstream runoff reduction practices and totaled in **cell I-121.**

12.1.3 TABs 3 through 6: Drainage Areas (D.A.'s) B through E (B, C, D, and E)

If there is only one drainage area for the site, sheet D.A. B, C, D and E should be left blank. If there is more than one Drainage area, fill out these tabs in the same manner as D.A. A.

12.1.4 TAB 7: Water Quality Compliance

6. The water quality compliance sheet summarizes the runoff reduction and pollutant removal results for the site. **Line 11** will indicate if additional TP load needs to be removed. If there is still a TP load to remove after applying runoff reduction and pollutant removal practices on D.A. A through D.A. E, the site should be reconfigured to reduce impervious or turf areas, or additional RR practices and pollutant removal practices must be selected on sheets D.A. A through D.A.B. The Total Nitrogen (TN) load reduction and adjusted site TN load will be calculated on **lines 20 and 22**. These are for informational purposes, as compliance is based on TP.

12.1.5 TAB 8: Channel and Flood Protection

This sheet assists with calculation of Adjusted Curve Numbers that can be used to calculate the channel protection and flood control volumes necessary for the site.

7. Compare the site area to the total watershed area draining to the point of discharge, and the post-development peak flow rate from the site for the 1-year 24-hour storm (see steps 8.A through 8.D below) to the 1-year 24-hour storm peak flow for the total watershed area draining to the point of discharge. If the site area is less than one percent of the watershed area, or the 1-year 24-hour post-development peak flow is less than one percent of the watershed peak flow rate from the 1-year 24-hour storm at the point of discharge, channel protection and flood protection requirements do not apply.

8.A Indicate the appropriate regional depths for the 1-year, 2-year, and 10-year 24-hour storms on **Line 2**.

8.B Each land cover and soil type is associated with a Natural Resource Conservation Service (NRCS) curve number. Using these curve numbers, a weighted curve number and the total runoff volume for each drainage area are calculated. For Drainage Area A, **Line 37** calculates the runoff volume without regard to the RR practices employed on the site. **Line 38** subtracts the volume treated by the RR practices from these totals. The s[readsjeet tjem deter,omes the cirve mi,ber tjat resi;ts om the ca;ci;ated rimpff vp;I,e wotj RR practices. This Adjusted Curve Number is reported on **line 39**.

These steps are repeated for Drainage Areas B through E**.**

Channel Protection Conditions

Detention or other means may be necessary to reduce the developed peak runoff to the allowable peak runoff values described below. Note that if, on sheets D.A. A through D.A. E, Extended Detention, Constructed Wetlands, or Wet Ponds are used, there may already be detention volume available to meet these requirements. Actual storage designed in the facility should be accounted for to calculate detention provided. Storage designed into bioretention, permeable pavement, or other practices can also be used to meet detention requirements, where the applicant can demontrate to the approval authority that the practice meets partial or complete detention requirements above and beyond the sizing required for water quality treatment.

9.A For manmade stormwater conveyance systems, demonstrate that the developed peak runoff from the 2-year 24-hour storm is conveyed without causing erosion of the system.

9.B For restored stormwater conveyance systems, demonstrate that the runoff from the developed site, in combination with other existing stormwater runoff, will be consistent with the design parameters of the system that is functioning in accordance with the design objectives.

9.C For natural stormwater conveyance systems, the maximum allowable peak flow rate from the 1-year 24-hour storm is equal to the following:

<u>Maximum Peak Flow Rate:</u>

Allowable $Q_{Developed} \leq I.F. \times Q_{Pre\text{-}Developed} \times RV_{Pre\text{-}Developed} / RV_{Developed}$

Where:

I.F. (Improvement Factor) = 0.8 for sites > 1 acre or 0.9 for sites ≤ 1 acre

Allowable $Q_{Developed}$ = the maximum allowable peak flow rate of runoff for the drainage area in the developed conditino (cubic feet per second)

$Q_{Pre\text{-}Developed}$ = the peak flow rate of runoff for the drainage area in the pre-developed condition (cubic feet per second)

$RV_{Pre\text{-}Developed}$ = the volume of runoff from the site in the pre-developed condition (inches)

$RV_{Developed}$ = the volume of runoff from the site in the developed condition, including runoff reduction (inches)

Flood Control Conditions

Detention or other means may be necessary to reduce the developed peak runoff to the allowable peak runoff values described below. Note that if, on sheets D.A. A through D.A. E, Extended Detention, Constructed Wetlands, or Wet Ponds are used, there may already be detention volume available to meet these requirements. Actual storage designed in the facility should be accounted for to calculate detention provided. Storage designed into bioretention, permeable pavement, or other practices can also be used to meet detention requirements where the applicant can demonstrate to the approval authority that the practice meets partial or complete detention requirements above and beyond the sizing required for water quality treatment.

10. Using the calculations under 8A. through 8.B. above, determine the peak discharge rates for the relevant water flood control storms.

11.A. For stormwater conveyance systems that currently do not experience localized flooding during the 10-year 24-hour storm event, the post-development peak flow rate for the 10-year 24-hour storm event is confined within the natural stormwater conveyance system.

11.B. For stormwater conveyance systems that currently experience localized flooding during the 10-year 24-hour storm event, confines the post-development peak flow rate from the 10-year 24-hour storm event within the stormwater conveyance system to avoid localized flooding or releases the post-development peak flow rate for the 10-year 24-hour storm event that is less than the pre-developed peak flow rate from the 10-year 24-hour storm event.

12.2 DOCUMENTATION FOR THE VIRGINIA RUNOFF REDUCTION METHOD

This section contains basic methods and computations that are built into the spreadsheet procedures. It combines the process with the equations. It is intended for users who want to verify or adapt the method.

12.2.1 Site Data Sheet

1.A Use environmental site design (ESD) techniques to reduce impervious cover and maximize forest and open space cover. This will affect the post-development treatment volume and pollutant load.

1.B The Target Phospherous Load is 0.41 pounds per acre per year, as indicated on **line 18**.

1.C For the site, indicate post-development impervious, managed turf, and forest/open space land cover in **lines 23-25**. Guidance for various land covers is provided in **Table 12.1** above.

2. From the land cover input, a weighted site runoff coefficient (R_v) will be calculated (**line 47**), as will the required Post Development Treatment Volume (**lines 49-50**).

Land Cover R_v:

$R_v(F) = [(A(fA) \times 0.02) + (A(fB) \times 0.03) + (A(fC) \times 0.04) + (A(fD) \times 0.05)]/SA$

$R_v(T) = [(A(tA) \times 0.15) + (A(tB) \times 0.20) + (A(tC) \times 0.22) + (A(tD) \times 0.25)]/SA$

$R_v(I) = 0.95$

$\%Forest = (A(fA) + A(fB) + A(fC) + A(fD))/SA \times 100$

$\%Turf = (A(tA) + A(tB) + A(tC) + A(tD))/SA \times 100$

$\%Impervious = (A(iA) + A(iB) + A(iC) + A(iD))/SA \times 100$

Where:

$R_v(F)$ = weighted forest runoff coefficient
A(fA) = area of post-development preserved or restored forest in A soils (acres)
A(fB) = area of post-development preserved or restored forest in B soils (acres)
A(fC) = area of post-development preserved or restored forest in C soils (acres)
A(fD) = area of post-development preserved or restored forest in D soils (acres)

$R_v(T)$ = weighted turf runoff coefficient
A(tA) = area of post-development managed turf in A soils (acres)
A(tB) = area of post-development managed turf in B soils (acres)
A(tC) = area of post-development managed turf in C soils (acres)
A(tD) = area of post-development managed turf in D soils (acres)

$R_v(I)$ = weighted impervious cover runoff coefficient
A(iA) = area of post-development impervious cover in A soils (acres)
A(iB) = area of post-development impervious cover in B soils (acres)
A(iC) = area of post-development impervious cover in C soils (acres)
A(iD) = area of post-development impervious cover in D soils (acres)

SA = total site area (acres)

Site R_v:

$R_v(S) = R_v\ (F) \times \%Forest + R_v\ (T) \times \%Turf + R_v\ (I) \times \%Impervious$

Where:

$R_v(S)$ = runoff coefficient for the site
R_v (F) = weighted forest runoff coefficient
R_v (T) = weighted turf runoff coefficient
R_v (I) = weighted impervious cover runoff coefficient

Post Development Treatment Volume:

$T_v\ (S) = Rd \times R_v\ (S) \times SA/12$

Where:

T_v (S) = post-development treatment volume for site (acre-ft)
Rd = rainfall depth for target event (1-inch for water quality storm)
R_v (S) = runoff coefficient for the site
SA = total site area (acres)

3. A Post Development TP Load, and the required TP load reduction will be calculated based upon the Post Development Treatment Volume (**lines 51-52**).

Post Development TP Load:

$L = P \times P_j \times [T_v\ (S)/Rd] \times C \times 2.72$

Where:

L = post-development pollutant load for site (pounds / year of total phosphorus)
P = average annual rainfall depth (inches) = 43 inches for Virginia
P_j = fraction of rainfall events that produce runoff = 0.9
T_v (S) = post-development treatment volume for site (acre-ft)
Rd = rainfall depth for target event (1-inch for water quality storm)
C = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for Total Phosphorus
2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Required TP Load Reduction:

$L_{Reduction} = L – P_{Target}$ x SA

Where:

$L_{Reduction}$ = required TP Load Reduction (pounds / year of Total Phosphorous
L = post-development pollutant load for site (pounds / year of Total Phosphorus)
P_{Target} = Target phosphorous load (pounds / acre / year)
SA = total site area (acres)

12.2.2 D.A. A

4. If the site has multiple discharge points, or complex treatment sequences, it may be beneficial to divide the site into more than one drainage area. Indicate the post-development impervious, managed turf, and forest/open space land cover for Drainage Area A in **lines 11-13**.

5.1.A. Apply Runoff Reduction (RR) Practices to the drainage area to reduce post-development treatment volume and load by indicating in **column G** the number of acres to be treated by a given RR practice. Note that some RR practices are divided into turf area and impervious area to be treated. The site designer should select the most strategic locations on the site to place RR practices (e.g., drainage areas with the most developed land). This will likely be an iterative process. The available RR Practices include:

- Green roof
- Impervious surface disconnection
- Permeable pavement
- Grass channel
- Dry swale
- Bioretention
- Infiltration
- Extended detention pond
- Sheetflow to conservation area or filter strip

5.1.B. Based upon the runoff reduction capability of the selected BMP, the spreadsheet will calculate the Runoff Volume Reduction in **column I** and the Remaining Runoff Volume in **column J.**

Adjustment to Treatment Volume:

$C_v(x) = (Rd \times R_v \text{ (land cover)} \times CA \times 3630 + V_{Upstream}) \times CR$

Where:

C_v (x) = Adjustment to treatment volume based on application of credit X (cubic feet)

Rd = rainfall depth for target event (1-inch for water quality storm)

R_v (land cover) = weighted runoff coefficient for land cover being treated by credit practice

CA = area credit applied to (acres)

3630 = unit adjustment factor, converting acre-inches to cubic feet

$V_{Upstream}$ = Upstream runoff volume directed to credit practice

CR = credit (fraction of runoff eliminated by the credit practice)

5.1.C. These practices also have a pollutant removal efficiency (**column K**), which will be applied to the remaining runoff volume (after runoff reduction has been applied). The spreadsheet will calculate the adjustment to the phosphorus load in **column N**:

Pollutant Load to the Practice:

$L(x) = L_{Upstream} + [R_v \text{ (land cover)} \times CA \times P \times P_j/12 - C_v (x)/43{,}560] \times 2.72 \times EMC$

Where:

L(x) = Pollutant Load to the Practice (pounds/yr)

$L_{Upstream}$ = Pollutant load from upstream treatment practices

R_v (land cover) = weighted runoff coefficient for land cover being treated by credit practice

CA = area credit applied to (acres)

P = average annual rainfall depth (inches) = 43 inches for Virginia

P_j = fraction of rainfall events that produce runoff = 0.9

12 = unit adjustment factor, converting acre-inches to acre-ft

43,560 = unit adjustment factor, cubic feet to acre-ft

C_v (x) = adjustment to treatment volume based on application of BMP credit ($ft.^3$)

EMC = flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for Total Phosphorus

2.72 = unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Pollutant Removal (or Load Reduction):

$LR(x) = L(x) * [C_v(x) + AT_v(x) * EFF_{TP} / 100] / [C_v(x) + AT_v(x)]$

Where:

LR(x) = Load Reduction (lbs/year)

L(x) = Load to the practice (lbs/year)

C_v (x) = adjustment to treatment volume based on application of BMP credit (cubic ft)
AT_v (x) = Remaining Runoff Volume after credit X is applied (cubic feet) (See 5.2A below)
EFF_{TP} = Total Phosphorus pollutant removal efficiency
100 = % conversion factor

5.2.A. If a secondary RR practice or a pollutant removal practice will be used in sequence downstream of the primary RR practice (for example, 2 acres of impervious rooftop are to be treated first with a green roof, and then, after discharge from the roof, will be conveyed via a dry swale), select the downstream RR practice from the pull-down menu in **column P** (click on the blue box in **column P** to see the pull-down menu). The spreadsheet will calculate the Remaining Runoff Volume and then direct it to the selected downstream RR practice via **column H**, and the remaining phosphorus load to **column L.** Sequences of three or more practices can be accommodated.

Remaining Runoff Volume:
AT_v (x) = (Rd x R_v (land cover) x CA x 3630 + $V_{Upstream}$) x (1 – CR)

Where:
AT_v (x) = Remaining Runoff Volume after credit X is applied (cubic feet)
Rd = rainfall depth for target event (1-inch for water quality storm)
R_v (land cover) = weighted runoff coefficient for land cover being treated by credit practice
CA = area credit applied to (acres)
3630 = unit adjustment factor, converting acre-inches to cubic feet
$V_{Upstream}$ = Upstream runoff volume directed to credit practice
CR = credit (fraction of runoff eliminated by the credit practice)

Remaining Phosphorus Load:
AL(x) = L(x) – LR(x)

Where:
AL(x) = Remaining Phosphorus Load after treatment by the practice (lb/year)
L(x) = Load to the practice (lbs/year)
LR(x) = Load Reduction (lbs/year)

5.2.B. Select all the RR practices that will be used for the drainage area. Note that it is possible for a RR practice to be a downstream practice for one area, and a primary practice for another. (Using the example above, a dry swale can receive discharge from a green roof and can also receive runoff directly from an impervious parking area.). It is also possible for more than one primary practice to be directed to the same downstream practice. However, the spreadsheet will not allow runoff from one primary practice to be diverted into two different downstream practices. If a site design calls for this, the site will need to be divided into separate drainage areas, or the design worksheet may be used instead of the spreadsheet.

5.3.A. From the selected RR practices, the total runoff reduction will be calculated on **line 80**, along with the TP load reduction achieved on **line 81.**

Total Adjustment to Treatment Volume:

$C_v = \sum C_v (x)$

Where:

C_v = Total adjustment to treatment volume for the drainage area through application of credits (cubic ft)

$C_v (x)$ = Adjustment to treatment volume based on application of credit X (cubic feet)

Total Load Reduction Achieved:

$LR_{RR} = \sum LR(x)$

Where:

LR_{RR} = Load Reduction achieved by Runoff Reduction Measures

$LR(x)$ = Pollutant Removal Achieved by individual runoff reduction practice (pounds)

5.3.B. The phosphorous load calculations on **lines 80 and 81** account for both the runoff reduction and pollutant removal achieved by runoff reduction practices. Additional practices, such as filters, ponds and wetlands remove phosphorous from runoff via settling, filtering, biological uptake, and other processes, but do not achieve runoff reductions. These practices should be viewed as supplemental to runoff reduction measures. **Lines 86-118** account for pollutant removal from practices that do not provide runoff reduction. In **Column D**, indicate acres of turf or impervious cover that drain to these practices *without* first being treated by another practice**.** The remaining phosphorus load and (unchanged) runoff volume can then be directed to a downstream practice chosen in **Column K.** Runoff volume and phosphorus load from upstream practices are included **Columns F and G**, respectively, for these practices.

5.3.C. The TP load reduction for the practices on **lines 86-118** are calculated in **Column I** and summed on **cell I-120**. This load is added to the phosphorus removal achieved by upstream runoff reduction practices and totaled in **cell I-121.**

Phosphorous Load Reduction:

$LR(x) = [L_{Upstream} + P \text{ x } Pi \text{ x } R_v \text{ (land cover) x } A/12 \text{ x EMC x } 2.72]\text{x } EFF_{TP} / 100$

Where:

$LR(x)$ = Pollutant Removal Achieved by individual BMP (pounds)
$L_{Upstream}$ = Phosphorus Load from upstream practices
P = Average annual rainfall depth (inches) = 43 inches for Virginia
$Rv(\text{land cover})$ = Weighted runoff coefficient for land cover being treated by the BMP
A = Area draining to the practice (acres)
EMC = Flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.26 mg/L for total phosphorus
12 = Unit adjustment factor, converting acre-inches to acre-ft
2.72 = Unit adjustment factor, converting milligrams to pounds and acre-feet to liters
EFF_{TP} = Total Phosphorus pollutant removal efficiency
100 = % conversion factor

Total Phosphorous Load Reduction:

$$LR = \sum LR(x) + LR_{RR}$$

Where:

LR = Total Pollutant Removal Achieved (pounds / year of Total Phosphorous)
$LR(x)$ = Pollutant Removal Achieved by individual BMP (pounds / year of Total Phosphorous)
LR_{RR} = Load Reduction achieved by Runoff Reduction Measures (lbs/year)

12.2.3 D.A. B thruogh D.A. E

If there is only one drainage area for the site, sheets D.A. B, C, D, and E should be left blank. If there is more than one Drainage area, fill out the appropriate number of these sheets in the same manner as D.A. A.

Water Quality Compliance:

6. The water quality compliance sheet summarizes the runoff reduction and pollutant removal results for the site. **Line 11** will indicate if additional TP load needs to be removed. If there is still a TP load to remove after applying runoff reduction and pollutant removal practices on D.A. A through D.A. E, the site should be reconfigured to reduce impervious or turf areas, or additional RR practices and pollutant removal practices must be selected on sheets D.A. A through D.A. E.

Channel and Flood Protection:

This sheet assists with calculation of Adjusted Curve Numbers that can be used to calculate the channel protection and flood control volumes necessary for the site.

7. Compare the site area to the total watershed area draining to the point of discharge, and the post-development peak flow from the site for the 1-year 24-hour storm (see steps 8.A-D below) to the 1-year 24-hour storm peak flow rate for the total watershed area draining to the point of discharge. If the site area is less than one percent of the watershed area, or the 1-year 24-hour post-development peak flow is less than one percent of the watershed peak flow at the point of discharge, channel protection and flood protection requirements do not apply.

8.A Indicate the appropriate regional depths for the 1-year, 2-year, and 10-year 24-hour storms on **Line 2**.

8.B Each land cover and soil type is associated with a Natural Resource Conservation Service (NRCS) curve number. Using these curve numbers, a weighted curve number and the total runoff volume for each drainage area are calculated. For Drainage Area A, **Line 37** calculates the runoff volume without regard to the RR practices employed on the site. **Line 38** subtracts the volume treated by the RR practices from these totals. The spreadsheet then determines the curve number that results in the calculated runoff volume with RR practices. This Adjusted Curve Number is reported on **line 39**.

These steps are repeated for Drainage Areas B – E.

Weighted Curve Number:

CN = [(A(fA) x 30) + (A(fB) x 55) + (A(fC) x 70) + (A(fD) x 77)+ (A(tA) x 39) + (A(tB) x 61) + (A(tC) x 74) + (A(tD) x 80) + A(iA) x 98) + (A(iB) x 98) + (A(iC) x 98) + (A(iD) x 98)] / DA

Where:

CN = weighted curve number
A(fA) = area of post-development preserved or restored forest in A soils (acres)
A(fB) = area of post-development preserved or restored forest in B soils (acres)
A(fC) = area of post-development preserved or restored forest in C soils (acres)
A(fD) = area of post-development preserved or restored forest in D soils (acres)

A(tA) = area of post-development managed turf in A soils (acres)
A(tB) = area of post-development managed turf in B soils (acres)
A(tC) = area of post-development managed turf in C soils (acres)
A(tD) = area of post-development managed turf in D soils (acres)

A(iA) = area of post-development impervious cover in A soils (acres)
A(iB) = area of post-development impervious cover in B soils (acres)
A(iC) = area of post-development impervious cover in C soils (acres)
A(iD) = area of post-development impervious cover in D soils (acres)

DA = Drainage Area (acres)

Potential Abstraction:
$S = 1000 / (CN-10)$

Where:

S	=	Potential Abstraction (inches)
CN	=	weighted curve number

Runoff Volume with no Runoff Reduction:
$V = (P – 0.2 \times S)^2 / (P + 0.8 \times S)$

Where:

V	=	Runoff volume with no runoff reduction (inches)
P	=	Precipitation depth for a given 24-hour storm (inches)
S	=	Potential Abstraction (inches)

Runoff Volume with Runoff Reduction:
$V_{rr} = V – C_v(da) / 3630 / DA$

Where:

V_{rr}	=	Runoff volume *with* runoff reduction (inches)
$C_v(da)$	=	Total adjustment to treatment volume for the drainage area through application of runoff reduction credits (cubic ft)
3630	=	Unit adjustment factor, cubic feet to acre-inches
DA	=	Drainage area (acres)

The spreadsheet then determines the curve number that results in the calculated runoff volume with RR practices. This adjusted curve number is reported on **lines 26 and 40.**

Adjusted Curve Number:
The adjusted curve number is calculated using a lookup table of curve number and runoff volumes so that:

$CN_{Adjusted}$, so $(P – 0.2 \times S_{Adjusted})^2 / (P + 0.8 \times S_{Adjusted}) = V_{rr}$

$S_{Adjusted} = 1000 / (CN_{Adjusted} – 10)$

Where:

$CN_{Adjusted}$	=	Adjusted curve number that will create a runoff volume equal to the drainage area runoff volume including runoff reduction practices
P	=	Precipitation depth for a given 24-hour storm (inches)
$S_{Adjusted}$	=	Adjusted potential abstraction based upon Adjusted Curve Number (inches)
V_{rr}	=	Runoff volume *with* runoff reduction (inches)

Channel Protection Conditions

Detention or other means may be necessary to reduce the developed peak runoff to the allowable peak runoff values described below. Note that if, on sheets D.A. A through D.A. E, Extended Detention, Constructed Wetlands, or Wet Ponds are used, there may already be detention volume available to meet these requirements. Actual storage designed in the facility should be accounted for to calculate detention provided. Storage designed into bioretention, permeable pavement, or other practices can also be used to meet detention requirements where the applicant can demonstrate to the approval authority that the practice meets partial or complete detention requirements above and beyond the sizing required for water quality treatment.

9.A For manmade stormwater conveyance systems, demonstrate that the developed peak runoff from the 2-year 24-hour storm is conveyed without causing erosion of the system.

9.B For restored stormwater conveyance systems, demonstrate that the runoff from the developed site, in combination with other existing stormwater runoff, will not exceed the design parameters of the restored stormwater conveyance system that is functioning in accordance with the design objectives.

9.C For natural stormwater conveyance systems, the maximum allowable peak flow rate from the 1-year 24-hour storm is equal to the following:

Maximum Peak Flow:

Allowable $Q_{Developed} \leq I.F. \times Q_{Pre\text{-}Developed} \times RV_{Pre\text{-}Developed} / RV_{Developed}$

Where:

I.F. (Improvement Factor) = 0.8 for sites > 1 acre or 0.9 for sites ≤ 1 acre

Allowable $Q_{Developed}$ = The maximum allowable peak flow rate of runoff for the drainage area in the developed condition (cubic feet per second)

$Q_{Pre\text{-}Developed}$ = peak runoff rate for the drainage area in the pre-developed condition (cubic feet per second)

$RV_{Pre\text{-}Developed}$ = The volume of runoff from the site in the pre-developed condition (inches)

$RV_{Developed}$ = The volume of runoff from the site in the developed condition, including runoff reduction (inches)

Flood Control Conditions

Detention or other means may be necessary to reduce the developed peak runoff to the allowable peak runoff values described below. Note that if, on sheets D.A. A through D.A. E, Extended Detention, Constructed Wetlands, or Wet Ponds are used, there may already be detention volume available to meet these requirements. Actual storage designed in the facility should be accounted for to calculate detention provided. Storage designed into bioretention, permeable pavement, or other practices can also be used to meet detention requirements where the applicant can demonstrate to the approval authority that the practice meets partial or complete detention requirements above and beyond the sizing required for water quality treatment.

10. Using the calculations under 8.A. through 8.B above, determine the peak flow rates for the relevant water flood control storms.

11.A. For stormwater conveyance systems that currently do not experience localized flooding during the 10-year 24-hour storm event, the post-development peak flow rate for the 10-year 24-hour storm event is confined within the natural stormwater conveyance system.

11.B. For stormwater conveyance systems that currently experience localized flooding during the 10-year 24-hour storm event, confines the post-development peak flow rate for the 10-year 24-hour storm event within the stormwater conveyance system to avoid localized flooding or releases the post-development peak flow rate for the 10-year 24-hour storm event that is less than the pre-developed peak flow rate from the 10-year 24-hour storm event..

12.3 SUPPLEMENTAL INSTRUCTIONS FOR USING THE REDEVELOPMENT VERSION OF THE RUNOFF REDUCTION METHOD SPREADSHEET

[NOTE: Sections 12.3 and 12.4, providing instructions for using the Redevelopment version of the Spreadsheet, are still under development.]

For redevelopment sites, use the following instructions for Tab 1: Site Data *instead of* those in **subsection 12.1.1** above. However, use the *remaining* instructions in **Section 12.1** for the remainder of the spreadsheet.

TAB 1. Site Data

1.A Use environmental site design (ESD) techniques to reduce impervious cover and maximize forest and open space cover. This will affect the post-development treatment volume and pollutant load.

1.B The Target Phosphorous Load is 0.41 pounds per acre per year, as indicated on **line 18**. However, load reductions are based on the percent reduction requirements noted in Step 3 for redevelopment sites.

1.C. For the site, indicate pre-development impervious, managed turf, and forest/open space land cover in **lines 23-25**. Then do the same for post-development in **lines 30-32**. Guidance for various land covers is provided in **Table 12.1** above.

2. From the land cover input, a weighted site runoff coefficient (R_v) will be calculated (**line 55**), as will the Pre- and Post-Development Treatment Volume (**lines 57-58**).

3. Pre- and post-development TP loads will be calculated (**line 59**). Using these values, the required TP Load Reduction will be calculated (**line 63**), based upon whichever of the following applies:

a. Decrease TP loads by 10% if the site disturbs less than 1 acre with no net increase in impervious cover.
b. Decrease TP loads by 20% if the site disturbs greater than or equal to 1 acre with no net increase in impervious cover.
c. New increases in impervious area over the pre-development condition must not exceed 0.41 pounds per acre per year of TP, and the remaining disturbed area must be either 3.a. or 3.b. above, as appropriate..
d. Decrease TP loads to a more stringent standard established by a qualifying local program if such exists. In this case, the appropriate values would have to be entered on **lines 18 and 61.**

A Total Nitrogen (TN) will also be calculated in **line 66** for informational purposes. However, compliance with the water quality requirements of the regulations is based *only* on TP.

12.4 SUPPLEMENTAL DOCUMENTATION FOR THE REDEVELOPMENT VERSION OF THE RUNOFF REDUCTION METHOD

This supplemental documentation applies to Tab 1: Site Data for redevelopment sites. **Section 12.2**, "Documentation for the Virginia Runoff Reduction Method" (page 10) provides the computation documentation for the remainder of the spreadsheet.

TAB 1: Site Data

1.A Use environmental site design (ESD) techniques to reduce impervious cover and maximize forest and open space cover. This will affect the post-development treatment volume and pollutant load.

1.B The Target Phosphorous Load is 0.41 pounds per acre per year, as indicated on **line 18**. However, load reductions are based on the percent reduction requirements noted in Step 3 for redevelopment sites.

1.C. For the site, indicate pre-development impervious, managed turf, and forest/open space land cover in **lines 23-25**. Then do the same for post-development in **lines 30-32**. Guidance for various land covers is provided in **Table 12.2** above.

2. From the land cover input, a weighted site runoff coefficient (R_v) will be calculated (**line 55**), as will the Pre- and Post-Development Treatment Volume (**lines 57-58**).

Land Cover R_v:

$R_v(F) = [(A(fA) \times 0.02) + (A(fB) \times 0.03) + (A(fC) \times 0.04) + (A(fD) \times 0.05)]/SA$
$R_v\ (T) = [(A(tA) \times 0.15) + (A(tB) \times 0.20) + (A(tC) \times 0.22) + (A(tD) \times 0.25)]/SA$
$R_v\ (I) = 0.95$
$\%Forest = (A(fA) + A(fB) + A(fC) + A(fD))/SA \times 100$
$\%Turf = (A(tA) + A(tB) + A(tC) + A(tD))/SA \times 100$
$\%Impervious = (A(iA) + A(iB) + A(iC) + A(iD))/SA \times 100$

Where:

R_v (F) = weighted forest runoff coefficient
A(fA) = area of pre- or post-development preserved or restored forest in A soils (acres)
A(fB) = area of pre- or post-development preserved or restored forest in B soils (acres)
A(fC) = area of pre- or post-development preserved or restored forest in C soils (acres)
A(fD) = area of pre- or post-development preserved or restored forest in D soils (acres)

R_v (T) = weighted turf runoff coefficient
A(tA) = area of pre- or post-development managed turf in A soils (acres)
A(tB) = area of pre- or post-development managed turf in B soils (acres)
A(tC) = area of pre- or post-development managed turf in C soils (acres)
A(tD) = area of pre- or post-development managed turf in D soils (acres)

R_v (I) = impervious runoff coefficient
A(iA) = area of pre- or post-development impervious cover in A soils (acres)
A(iB) = area of pre- or post-development impervious cover in B soils (acres)
A(iC) = area of pre- or post-development impervious cover in C soils (acres)
A(iD) = area of pre- or post-development impervious cover in D soils (acres)

SA = total site area (acres)

Site R_v:

Rv(S) = Rv(F) x %Forest + Rv(T) x %Turf +Rv(I) x %Impervious

Where:

R_v (S) = runoff coefficient for the site
R_v (F) = weighted forest runoff coefficient
R_v (T) = weighted turf runoff coefficient
R_v (I) = weighted impervious cover runoff coefficient

Treatment Volume:

$T_v\ (S) = Rd \times R_v(Site) \times SA/12$

Where:

T_v (S)	=	pre- or post-development treatment volume for site (acre-ft)
Rd	=	rainfall depth for target event (1" for water quality storm)
R_v(Site)	=	runoff coefficient for the site
SA	=	Site area

3. A Pre- and Post-Development TP Load will be calculated (**line 59**). Using these values, the required TP Load Reduction will be calculated (**line 63**) based upon whichever of the following applies:
   a. Decrease TP loads by 10% if the site disturbs less than 1 acre with no net increase in impervious cover.
   b. Decrease TP loads by 20% if the site disturbs greater than or equal to 1 acre with no net increase in impervious cover.
   c. New increases in impervious area over the pre-development condition must not exceed 0.41 pounds per acre per year of TP, and the remaining disturbed area must be either 3.a. or 3.b. above, as appropriate.
   d. Decrease TP loads to a more stringent standard established by a qualifying local program, if such exists. In this case, the appropriate values would have to be entered on **lines 18 and 61**.

TP Load:

$L = P \text{ x } P_j \text{ x } [T_v(S)/Rd] \text{ x } C \text{ x } 2.72$

Where:

L	=	pre- or post-development pollutant load for site (pounds / year of total phosphorus)
P	=	average annual rainfall depth (inches) = 43 inches for Virginia
P_j	=	fraction of rainfall events that produce runoff = 0.9
T_v (S)	=	pre- or post-development treatment volume for site (acre-ft)
Rd	=	rainfall depth for target event (1" for water quality storm)
C	=	flow-weighted mean concentration of pollutant in urban runoff (mg/L) = 0.28 mg/L for total phosphorus
2.72	=	unit adjustment factor, converting milligrams to pounds and acre-feet to liters

Required TP Load Reduction:

$L_{Reduction} = L_{Post} - 0.8 \text{ x } L_{Pre}$ ***OR*** $L_{Reduction} = L_{Post} - P_{Target} \text{ x } SA$
(whichever value is less)

Where:

$L_{Reduction}$	=	Required TP Load Reduction (pounds/year of total phosphorous
L_{Post}	=	Post-development pollutant load for site (pounds/year of total phosphorous)
L_{Pre}	=	Pre-development pollutant load for site (pounds/year of total phosphorus)
P_{Target}	=	Target phosphorous load (pounds/acre/year)
SA	=	Total site area (acres)